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Strategies for the Assessment of Inquiry Learning in Science (SAILS) A European Project in Science Teacher Education

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Abstract

The SAILS - Strategies for Assessment of Inquiry-based Learning in Science - project (2012-2015) [1] has been funded by EU 7th Framework Programme to support teachers in adopting inquiry-based science education (IBSE) at the secondary level. In particular, the SAILS project will develop appropriate strategies and frameworks for the assessment of IBSE skills and competences and prepare teachers not only to be able to teach through IBSE, but also to be confident and competent in the assessment of their students' learning. The project consortium consists of fourteen partner organisations, including universities, small companies and a multi-national organisation, from across twelve European countries: Belgium, Denmark, Germany, Greece, Hungary, Ireland, Poland, Portugal, Slovakia, Sweden, Turkey and the United Kingdom. The SAILS project has three main objectives: (1) to enhance existing IBSE teaching and learning materials by incorporating inquiry assessment strategies and frameworks; (2) to partner with teachers to identify and implement assessment strategies and frameworks to evaluate key IBSE skills and competences in the classroom; and (3) to provide teacher education programmes in IBSE and promote a self-sustaining model to encourage teachers to share experiences and practice of inquiry approaches to teaching, learning and assessment - by supporting a community of practice. This paper will discuss the concept and rationale of this project and present the design research approach adopted for carrying out this large-scale European project.

1. Introduction

Education and training have been central to the Lisbon agenda for growth and jobs and again take primary focus supporting the "smart growth" priority of the growth strategy for 2010-2020 [2]. More than ever, Europe's success in global competition is dependent on effective partnerships between business and academia to ensure that education delivers "high-level and highly valued skills", as presented in the 2010 EC Working document on the European 2020 Flagship Initiative [3]. In addition, the European Framework for Key Competencies for Lifelong Learning [4] identifies and defines the following eight key competences necessary for personal fulfilment, active citizenship, social inclusion and employability in a knowledge society and recommends that initial education and training should support their development:

- Communication in the mother tongue;
- Communication in foreign languages;
- Mathematical competence and basic competences in science and technology;
- Digital competence;
- Learning to learn;
- Social and civic competences;
- Sense of initiative and entrepreneurship;
- Cultural awareness and expression.

Employers have also stated that they need a workforce fully equipped with skills beyond the basics of reading, writing and arithmetic to grow their businesses, including:

- Critical thinking and problem solving: the ability to make decisions, solve problems and take action as appropriate.

- Effective communication: the ability to synthesize and transmit ideas in both written and oral formats.
- Collaboration: the ability to work effectively with others, including those from diverse groups and with opposing points of view.
- Creativity and innovation: the ability to see what's not there and make something happen [5]

However, many employers have identified that "high school graduates were 'deficient' in problem solving and critical thinking" [6]. In addition to the above, there has been a recent trend across the EU towards competence-based teaching and learning and a learning outcome approach [7], resulting in significant changes occurring at school curricula level in traditional subject areas such as science. These curricula are now being treated in more engaging cross-curricular ways, with greater emphasis being placed on developing skills and positive attitudes towards science alongside knowledge and with increased use of "real-life" applications to provide appealing learning contexts.

2. Inquiry Based Science Education

Crucial to the development of key competencies in young people is their engagement in the education process. Methodologies such as inquiry-based science education (IBSE) have been highlighted as having the potential to increase student engagement in science at primary and second level and provide such development opportunities [8, 9]. Recommendations from these international reports identify the need for "engaging curricula to tackle the issue of out-of date and irrelevant contexts and to enable teachers to develop their knowledge and pedagogical skills".

The global network of science academies [10] also supports the reform of science education on a global scale by encouraging hands-on inquiry-based learning (IBSE), especially in primary and secondary schools – where they define IBSE as comprising of "experiences that enable students to develop an understanding about the scientific aspects of the world around through the development and use inquiry skills." In their 2006 Working Group on the International Collaboration in the Evaluation of IBSE programs report [11] they discuss IBSE in practice and conclude that, while there is no single model of IBSE, there are recognised features of the classroom activities that indicate IBSE is taking place, such as students will be:

- "engaged in observation and, where possible, handling and manipulating real objects;
- pursuing questions which they have identified as their own even if introduced by the teacher;
- taking part in planning investigations with appropriate controls to answer specific questions;
- using and developing skills of gathering data directly by observation or measurement and by using secondary sources;
- using and developing skills of organising and interpreting data, reasoning, proposing explanations, making predictions based on what they think or find out;
- working collaboratively with others, communicating their own ideas and considering others' ideas;
- expressing themselves using appropriate scientific terms and representations in writing and talk;
- engaging in lively public discussions in defence of their work and explanations;
- applying their learning in real-life contexts;
- reflecting self-critically about the processes and outcomes of their inquiries."

The European Commission, having identified IBSE as a desirable methodology to implement in classrooms across Europe to engage young people in science and mathematics and develop skills and competencies to cope with the challenges for a changing world, have funded a number of projects in IBSE such as S-TEAM (www.s-teamproject.eu), ESTABLISH (www.establish-fp7.eu), Fibonacci, (www.fibonacci-project.eu), PRIMAS (www.primas-project.eu) and Pathway (www.pathway-project.eu).

3. Project Concept

The aim of the SAILS project is to equip teachers across Europe with assessment strategies to evaluate a number of key IBSE skills and competencies developed in the classroom, when an IBSE methodology is adopted. Using existing materials already developed in similar European IBSE initiatives the assessment

strategies provided by SAILS will enable teachers to recognise and evaluate the benefits of teaching by this methodology. The inquiry approach in science teaching has been defined as the "intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments" [12]. Thus it requires more of the learner than simply commanding and recalling scientific knowledge. Through this deeper engagement process students are presented with more opportunities to foster initiative-taking, creativity and innovation in schools.

We assert that to fully employ the potential of IBSE, it is paramount that the assessment component of the model given in Figure 1 is given due prominence. Therefore, SAILS aims to build on the existing IBSE curricula and Teacher Education (TE) programmes, motivate and support current practitioners of IBSE in the classroom, and in addition, develop a systematic approach to the assessment of IBSE skills.

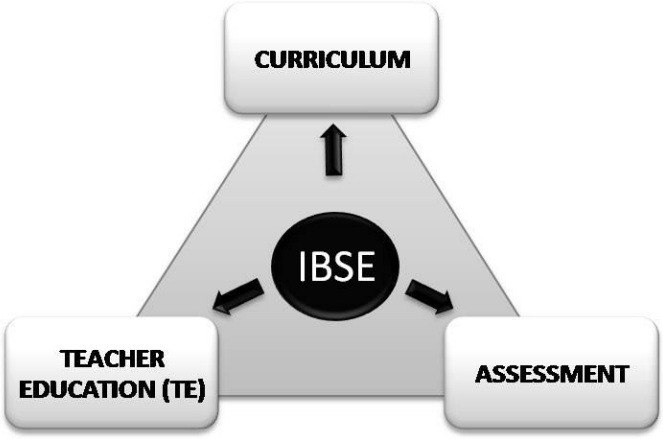

Figure 1. *The role of curriculum, teacher education and assessment in the improved model of IBSE advocated by SAILS.*

For many students and teachers, assessment drives the activities in a classroom. As stated above, most current assessment methods have a strong emphasis on knowledge recall and do not sufficiently capture the crucial skills and attitudes dimension of key competencies. Current and existing models of assessment are typically at odds with the high-level skills, knowledge, attitudes and characteristics of self directed and collaborative learning that are increasingly important for our global economy and fast changing world. Moreover, if something is assessed, then it is more highly valued, by teachers and students alike; hence, if the competencies and skills as noted here remain un-assessed, then the development of these skills and competencies will always be secondary to recall and routine problem solving. SAILS works to address these issues by providing teachers with assessment strategies that will prove the effectiveness and efficacy of IBSE to develop desired skills and competencies as well as providing a metric for industry to assess students' capabilities in the different skills areas.

4. Project design and approach

The overall SAILS project design and approach is depicted in Figure 2. As stated above, resources for IBSE that have been developed through other projects are used as the starting point for SAILS. The initial stage of the project involved the selection of appropriate teaching and learning materials that were good examples of inquiry. These materials were then critiqued to identify the main inquiry skill(s) that could be developed through these activities. It is clear that development of inquiry skills is a process that occurs over time and so it was necessary to develop materials to encompass a range of inquiry skills. Additionally, opportunities for group work and classroom dialogue were identified.

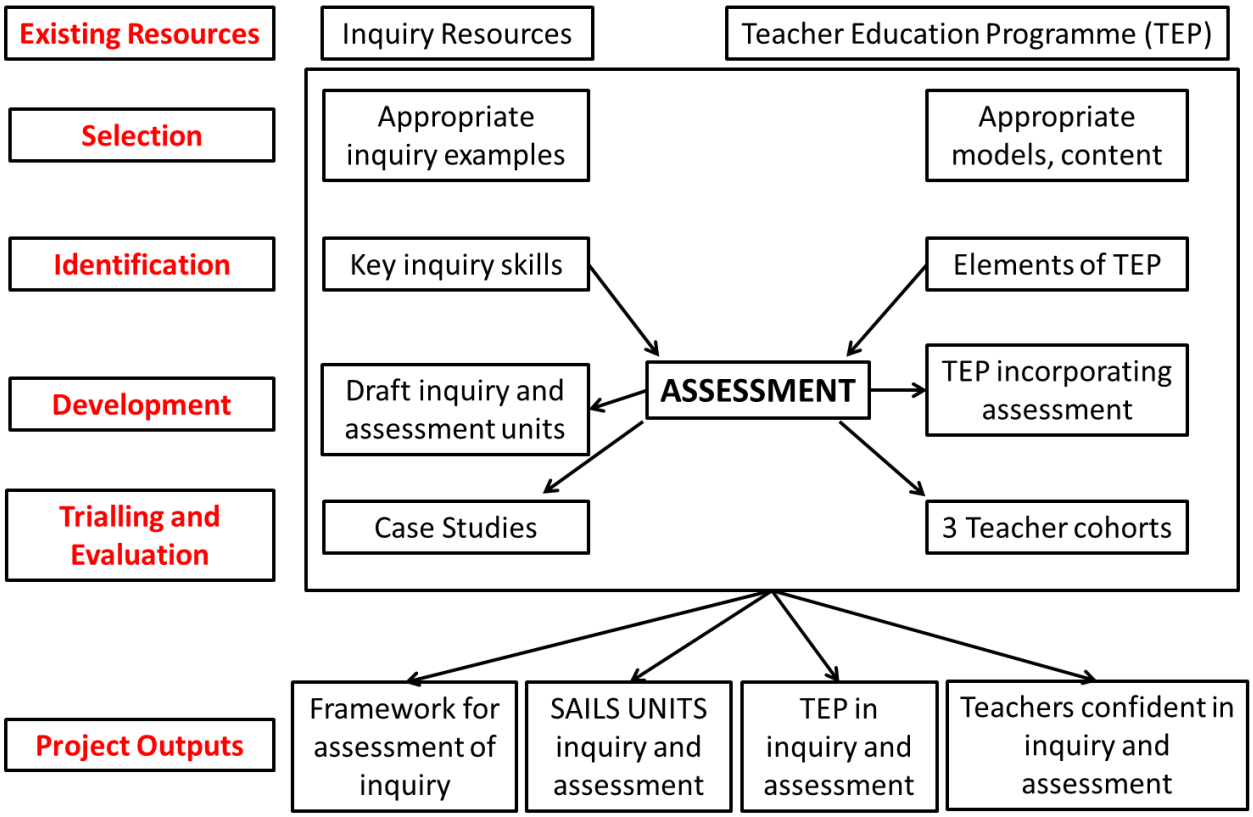

Figure 2. *SAILS project design and approach*

These materials were further developed to present models and materials for the assessment of the inquiry skills. Three different areas for assessment were identified, namely assessment of conceptual knowledge; assessment of reasoning processes and assessment of inquiry skills. Informed by expertise within the group, and literature, opportunities for assessment were identified in the activities; however, it was clear that teachers could not trial all aspects of these suggestions. Draft Units were prepared that presented the inquiry approach and offered a selection of opportunities for assessment of the inquiry skills, along with criteria proposed for that assessment. Pilot teachers whom were experienced in IBSE were selected in each country to trial these draft units in their classrooms. The teachers recorded their experiences in the form of Case Studies which outlined the practice of the assessment, the criteria used in the assessment and their planned follow up as a consequence of that assessment. The evaluation of the draft units and case studies was based on trialling inquiry and assessment materials in four different countries. The final stage of the project involved collating and presenting the inquiry and assessment materials developed into final Sails Units. This overall approach adopted by SAILS has led to the development of a Framework for Assessment of Inquiry Skills, which is also a useful resource for all teachers.

In parallel to this process for developing inquiry and assessment materials, all participating countries have developed a Teacher Education Programmes (TEP), with both in-service and pre-service teachers, that offers education in IBSE methodologies and also in the assessment of IBSE practices. The final TEPs have been developed in each country, are in accordance with the SAILS Framework for TEPs, and embed the assessment of IBSE within teacher education in inquiry methodologies.

A key output from the SAILS project is the number of teachers across Europe whom have participated in TEPs across the lifetime of the project and who have gained confidence and competence in teaching and assessing IBSE.

5. Conclusions

To tackle this global challenge of encouraging and supporting teachers to implement an inquiry approach and to be confident and competent in their use of inquiry and assessment in their classrooms requires a large scale focus. Therefore the SAILS project has been designed to incorporate the expertise of 14 partner institutions and organisations across 12 countries to work with local practitioners and stakeholders to address this issue. The collaborative efforts of this project consortium in identifying, developing and trialling inquiry and assessment materials has led to the development of 20 SAILS Units in inquiry and assessment. In particular, models for the implementation of appropriate teacher education programmes for inquiry and assessment have been identified and developed by the consortium and trialled with several teacher cohorts in each country. Further details on all of these project outputs and outcomes can be found on the project website [1]. A further positive outcome of this project is that it has resulted in an increase in national debate and discussion on the importance of assessment within the educational continuum and how new practices are needed to promote the key skills that has been identified by employers, educators and others as necessary for the informed 21st century citizen.

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